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LOCAL CLIMATIC AND HYDROLOGIC CONSEQUENCES OF CREATING OPENINGS IN CLIMAX TIMBER OF NORTH IDAHO

Harold F. Haupt



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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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ACKNOWLEDGMENT

This report has an unsung hero, B. L. Jeffers, hydrologic technician, who faithfully maintained instruments and collected field data, oftentimes under adverse weather conditions. The overall high quality of data can be attributed to his skills and perseverance.

RESEARCH SUMMARY

Climatic and hydrologic responses of small and large clearcuts on north and south aspects in northern Idaho were studied. The parameters-- surface wind, maximum snow deposition, seasonal precipitation, and seasonal percolation--were related to the distance downwind from the west edge of the forest by sets of linear models. On the north aspect an exponential increase in each parameter generally occurred as the distance increased. On the south aspect, the same response was observed with surface wind. However, maximum snow deposition, seasonal precipitation, and seasonal percolation increased for a short distance of 1.0 to 2.0 tree heights and then diminished rapidly. Other attributes such as drip, snow interception, snowmelt, and rates of disappearance were evaluated with supportive data.

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INTRODUCTION

Practicing hydrologists, foresters, and big game biologists have a continuing need for information about the climatic-hydrologic consequences of creating openings in old climax timber. New information was gained recently from a study conducted in the Priest River Experimental Forest, an area which typifies much of the sloping forested land of northeastern Washington, northern Idaho, and western Montana.

The specific objectives of the study were to detect changes in surface wind, precipitation amount, snow deposition and ablation, snow depth and density, and percolation associated with a variety of clearings situated on north and south aspects. The investigation was conducted from November through May over 5 study years.

EARLIER INFORMATION

Little wintertime work has been done in northern Idaho that has dealt specifically with the local climate and hydrology of different sizes of forest openings. Packer (1962, 1971) summarized the results of a comprehensive snow course study conducted in the Priest River Experimental Forest, in which the effect of very small openings was studied. Larger openings, characterizing the usual timber sale, were not available at the time Packer reported and so were not studied. In recent years, larger openings have become available through a series of timber sales. Cline and others (1977) intensively instrumented two of these openings to determine snow deposition, snowmelt, percolation rates, soil water content, and potential water yield. This effort provided considerable basic data, part of which have been incorporated into this report.

EXPERIMENTAL SITE

The Priest River Experimental Forest is a 6,378-acre (2,577-ha) tract in the Idaho Panhandle National Forests north of Priest River, Idaho. Mountainous terrain, with elevations ranging from 2,200 to 5,900 feet (671 to 1,798 m), makes up 85 percent of the Experimental Forest. The specific study area overlapped onto both slopes of an east-west oriented ridge between an elevation of 4,000 and 4,600 feet (1,200 and 1,400 m). The south (180°) slope includes the Douglas-fir/ninebark habitat type; the open overstory consists of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco), western white pine (*Pinus monticola* Dougl.), western larch (*Larix occidentalis* Nutt.), and grand fir (*Abies grandis* [Dougl.] Forbes) and the understory contains a mixture of shrubs dominated by ninebark (*Physocarpus malvaceus* [Green] Kuntze). The north (335°) slope is classified as western hemlock/*Pachistima* habitat type (Daubenmire and Daubenmire 1968). The dense overstory was mainly western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), western redcedar (*Thuja plicata* Donn.), and western white pine, and the understory contains scattered *pachistima* shrub (*Pachistima myrsinites*), and low, herbaceous plants.

Soils in the higher elevations of the Experimental Forest are underlain by Precambrian metamorphic rock. The soils, which are derived from glacial till and are capped by a thick layer of volcanic ash, are predominantly silt loam.

The climate is influenced by the Pacific Ocean, hence the winters are cool and wet. Summers are dry. Storms and accompanying winds generally move in from the southwest, and, to a lesser degree, from the west and south. Most of the annual precipitation, about 40 inches (102 cm), falls from November through May in form of snow and rain. Precipitation for the years 1969-73 was average to above average. The last of the 5 study years, 1973, had the lowest total, 28 inches (72 cm), recorded since 1940.

STATION LOCATION

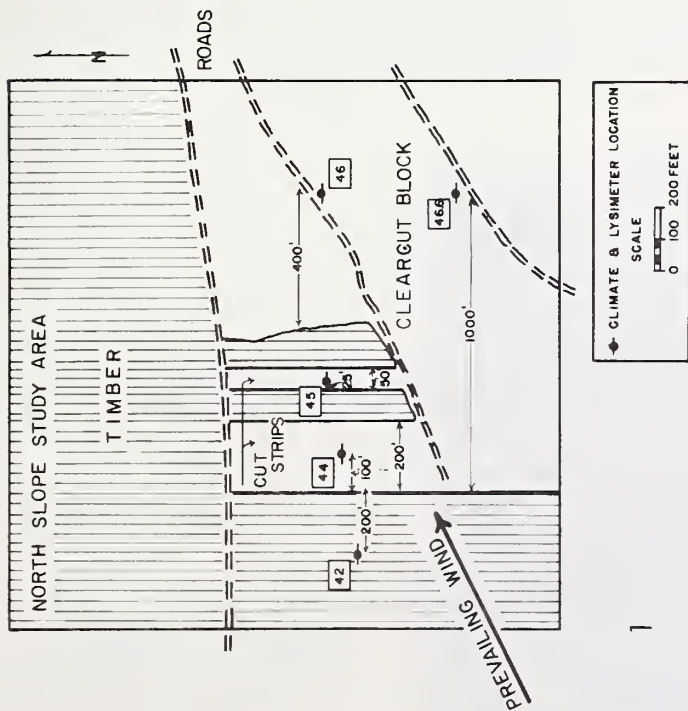
On both the north and south aspects, instrumented stations were located in openings that were clearcut logged in 1968 and 1969. One exception, station N39(0), was positioned in an isolated clearing carved out of the old stand in the 1930's. Stations N45(0) and N44(0) (north) and stations S49(0) and S50(0) (south) were established at the midpoint of individual stripcuts with long axis oriented north-south. Stations N46(0) and N46.6(0) (north) and stations S52(0) and S52.2(0) (south) were positioned in a clearcut block at different distances from the west edge of the forest; the north clearcut block was 65 acres (26 ha), the south, 25 acres (10 ha). The forest or "control" locations are represented by stations N40(T) and N42(T) (north) and S47(T) and S47.7(T) (south).

The descriptive character of each clearing and control site is given in table 1. Schematic diagrams in figures 1, 2, and 3 show how far each station is from the west edge of forest. It is important that the strip cuts opened onto the clearcut blocks whereas the clearing with station N39(0) was surrounded by trees.

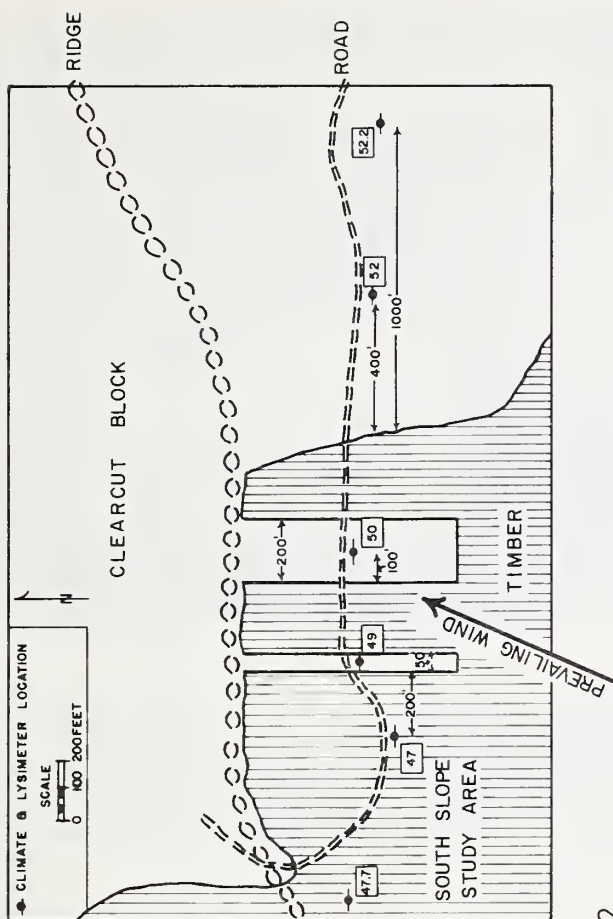
Table 1.--Description of stations, Priest River Experimental Forest, Idaho

Station	Aspect	Description of station site					Year of record					
		Elevation	Slope	Climatic station	Snow lysimeter	Angle ¹		Dimensions: (or acres)	Shape of clearing	Distance to (west) edge of timber	Slash disposal in clearing	
		Feet	Percent			Degrees			Feet			
40	N	4,000	27	Yes	Yes	90				Mature-size tree heights, 150 ft; crown closure (91% overhead, 90-100% surrounding)		1968-73
39	N	4,000	30	Yes	Yes	49	100x110 ft	Rounded	Climatic-50 Lysimeter-86		Removed by skidding	1968-73
42	N	4,300	48	Yes	Yes	90			0	Mature-size tree heights, 120-150 ft; crown closure (89% overhead; 85-95% surrounding)		1968-73
45	N	4,300	38	Yes	Yes	65	50x600 ft, long axis oriented N-S	Rectangular	25		Removed by skidding	1968-73
44	N	4,300	47	Yes	Yes	42	200x625 ft, long axis oriented N-S	Rectangular	100		Tractor piled and burned	1968-73
46	N	4,300	46	Yes	Yes	14	65 acres	Irregular block	400		Broadcast burn	1968-73
46.6	N	4,500	46	No	Yes		65 acres	Irregular block	1,000		Broadcast burn	1970-73
47.7	S	4,600	45	No	Yes					Pole-size tree heights, 40-60 ft; crown closure (65% overhead; 60-70% surrounding)		1970-73
47	S	4,600	44	Yes	Yes	90			0	Mature-size tree heights, 100 ft; crown closure (38% overhead; 30-40% surrounding)		1969-73
49	S	4,600	51	Yes	Yes	54	50x650 ft long axis oriented N-S	Rectangular	25		Removed by skidding	1969-73
50	S	4,600	52	Yes	Yes	39	200x650 ft, long axis oriented N-S	Rectangular	100		Removed by skidding	1969-73
52	S	4,600	53	Yes	Yes	11	25 acres	Irregular block	400		Broadcast burn	1969-73
52.2	S	4,600	52	No	Yes		25 acres	Irregular block	1,000		Broadcast burn	1970-73

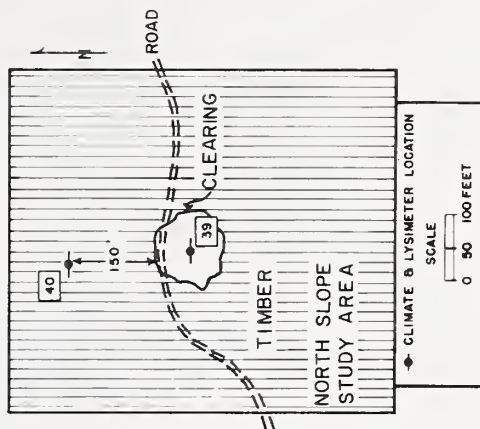
¹Angle of shielding from horizon of precipitation gage.



1



2



3

Figure 1.--North slope study area, Priest River Experimental Forest stations 42, 44, 45, 46, and 46.6).

Figure 2.--South slope study area (stations 47.7, 47, 49, 50, 52, and 52.2), Priest River Experimental Forest.

Figure 3.--North slope study area (stations 39 and 40), Priest River Experimental Forest.

MEASUREMENT TECHNIQUES

Each year of study, all precipitation was measured from November 1 through May 31. Snow courses, recording rain gages, and snow lysimeters were located at or near each station. Two parallel snow courses, each following the contour, crossed the area adjacent to the stations. They began in the clearcut block, ran across the strip cuts and contiguous leave strips, and ended well in the forest. Each course included 48 snow sampling points. Snow conditions at stations N39(O) and N40(T) were sampled, along snow courses, with six sampling points each. Water equivalent (W.E.) was measured periodically with a federal snow sampler during the accumulation-melt period, but only those readings taken at peak snowpack are discussed.

Precipitation in the clearings and throughfall and drip in the forest were measured by a recording rain gage. A single gage was placed midway across the cut strip or at predetermined distances from the edge of the forest (see table 1, Distance to (west) edge of timber). The gage in the forest was placed beneath canopies that best represented surrounding conditions. Prior to autumn 1970, gages were equipped with standard horizontal orifices and windshields. These were replaced with stereo orifices and tilted windshields (fig. 4) when it became evident that considerable precipitation was not being caught in the south aspect gages (Haupt 1972a).

Percolate was collected by snow lysimeters (Haupt 1969, 1972a) operated from November 1 through May 31. Lysimeters were positioned near the rain gages. In the forest, they were located beneath a canopy configuration similar to that above the rain gage. Lysimeters provided point measurements of net precipitation--precipitation that percolated through the snowpack during rainy periods or ultimately entered the soil mantle as the snowpack melted. A lysimeter is shown in late fall in figure 5A and in late winter in figure 5B.

Windspeed was measured with a 3-cup totalizer at each climatic station location.

Not every station was activated the fall of 1968. The south aspect replication came into operation 1 year later. Three stations, N46.6(O), S47.7(T), and S52.2(O), had lysimeters only. Years of total record are presented in table 1.



Figure 4.--Precipitation and anemometer station 52 located in large clearing (windward aspect).



Figure 5.--A. Snow lysimeter, station 52.2. Pan with frame, sliding collar, and polyethylene bag attached. B. Snow lysimeter, station 42. Lysimeter frame (second module) extending above a depth of snow of 48 inches (122 cm). Completely hidden is a separating layer of polyethylene.

DATA COMPILATION

Data for individual station-years are compiled and averaged in appendix A (table A1-surface wind, table A2-maximum snow deposition, table A3-seasonal precipitation, and table A4-seasonal percolation) for those practitioners who wish to delve into station-by-station, year-by-year average variations. The actual precipitation measurements as well as those corrected for wind are shown in table A3. Only the adjusted totals are modeled and discussed in the main text.

The study design did not include pretreatment measurements to determine if inherent site differences existed. However, posttreatment differences between some totals and means are large and intuitively important. Discretion would be appropriate when interpreting differences of less than 10 percent that could be caused by inherent site differences.

PARAMETRIC MODELING

The climatic parameters--surface wind, maximum snow deposition, seasonal precipitation, and seasonal percolation--were thought to relate to the divergent conditions existing on north and south aspects and to distance away (or downwind) from the edge of forest. The four basic relationships may be expressed for the individual climatic parameter as:

$$\begin{aligned}V_s &= f(D) \\W.E. &= f(D) \\ \Sigma P &= f(D) \\ \Sigma I &= f(D)\end{aligned}$$

where V_s is mean seasonal windspeed approximately 6 feet (1.8 m) above the snow surface; $W.E.$ is snow water equivalent at time of maximum depth; ΣP is the total seasonal precipitation; or ΣI is the total seasonal percolation and D represents the horizontal distance from edge of forest in feet.

Sets of linear models were derived for most aspect conditions and are shown with corresponding R-squares in Table 2. Two south aspect conditions could not be mathematically modeled to an acceptable degree of accuracy.

Table 2.--Models for predicting seasonal windspeed, maximum snow deposition, seasonal precipitation and percolation on two major aspects

Aspect	Model	r^2	$S_{y.x}$	F
Seasonal Windspeed				
North	$V_s = 2.2299 - 0.6443 \left(\frac{1}{D+1}\right) + 0.00532(D+1)$	0.806	0.281	31.078
South	$V_s = 4.9482 - 2.4097 \left(\frac{1}{D+1}\right) + 0.00347(D+1)$	.823	.509	30.243
Maximum Snow Deposition				
North	$WE = 2.2704 D^{0.229495}$	.680	.043	34.031
South	No model derived			
Seasonal Precipitation				
North	$\Sigma P = 1.06371 D^{0.43714} (0.99977)^D$	.986	.062	491.593
South	$\Sigma P = 1.1988 D^{0.4079} (0.9972)^D$	.869	.363	29.859
Seasonal Percolation				
North	$\Sigma I = 0.05494D - 0.000045 D^2$	.924	5.674	104.115
South	No model derived			

EFFECTS OF TOPOGRAPHY AND FOREST CLEARING ON LOCAL CLIMATE

Surface Wind

Table 3 shows the mean seasonal windspeeds by aspect and distance from the west edge of forest. These are average values for all kinds of weather during the 7-month period, therefore the speeds are small. Nevertheless, the overall mean windspeed was nearly two-thirds greater on the south (windward) aspect than on the north (lee) aspect. The differential was even greater for stations farthest from the forest edge (table 3).

Table 3.--Mean seasonal windspeed for years 1970, 1971, 1972, and 1973

Aspect	Distance from edge of timber					
	400	100	50 ¹	25	0 ²	0 ³
----- Feet second ⁻¹ -----						
North	4.6 (1.4) ⁷	2.7 (0.8)	1.3 ⁴ (0.4)	2.6 (0.8)	1.6 ⁵ (0.5)	1.2 ⁶ (0.4)
South	6.3 (1.9)	5.6 (1.7)		4.7 (1.4)	2.5 (0.8)	

¹Station 39.

²North - station 42; south - station 47.

³North - station 40.

⁴Years 1970, 1971, and 1972. Anemometer inoperative much of 1973.

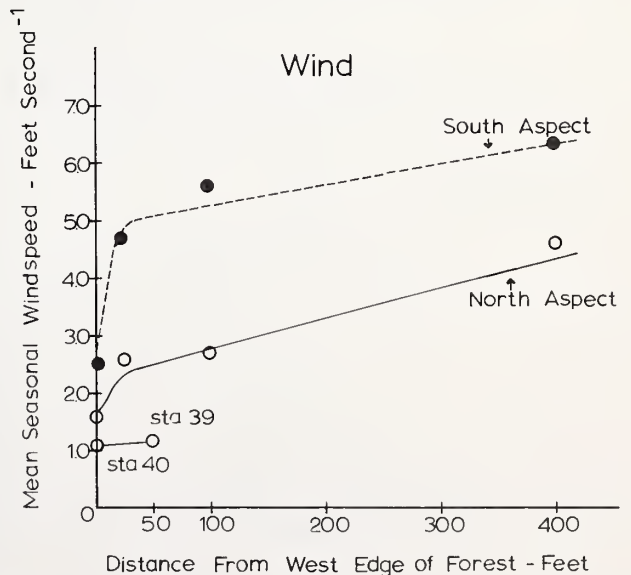
⁵Years 1971, 1972, and 1973. Anemometer inoperative much of 1970.

⁶Years 1970 and 1971. Anemometer inoperative much of 1972 and 1973.

⁷Italicized units in meters second⁻¹.

The line plots of windspeed derived from equations in table 2 are shown in figure 6. Shape of the curves resembles those of Reifsnnyder (1955) in his study of profiles downwind from a small isolated forest stand. Despite the limited number of stations, the models fit the data reasonably well except for one outlier, north station N39(0). That station was plotted separately in relation to the control, north station N40(T). Station N39(0) is completely surrounded by tall timber, which greatly restricts the freedom of air movement; the cut strips are incompletely surrounded, which allows more surface air movement.

Figure 6.--Mean seasonal windspeed by aspect. Closed circles represent south stations, open circles represent north stations.



Summary.--Aspect differences in windspeed were pronounced. Larger openings in the timber were associated with greater windspeed regardless of aspect. Trees that completely circumscribed a small clearing greatly reduced windspeed across the opening.

Maximum Snow Deposition

Snow water equivalent measured at the peak during late winter has been the traditional approach for evaluating site differences under wintertime conditions. Average date of maximum depth on north aspect occurred on March 19, or 15 days later than on the south aspect. These average dates may be early because the melt season was atypical during 1972 and 1973. The long-term record for nearby Benton Creek snow course (USDA, Soil Conservation Service 1975) indicates that maximum depths apparently occur 7 to 10 days later on either aspect or mid-March on the south aspect and late March on the north.

The modeled relationship of snow deposition as a function of distance from the edge of forest (table 4) appears in figure 7; the station-by-station profiles for both aspects are plotted in figure 8.

South aspect.--Gains compared to forest conditions increased to 1.9 inches (5 cm) and then declined after a distance of 1.0 tree height away from the edge. No real gain was measured beyond 4.0 tree heights in the average year (table 4).

Table 4.--Comparison of gains in clearings for station-years 1970-73

Distance from west edge of timber <i>Feet</i>	North <i>Inches</i>	South
Maximum Snow Deposition (WE)		
0 ¹	0	0
25	+4.4 (11.2) ⁵	+1.9 (4.8)
50	+5.6 (14.2)	
100	+6.6 (16.8)	+1.6 (4.1)
400	+8.6 (21.8)	+0.4 (1.0)
1,000 ²	+10.8 (27.4)	+0.1 (0.3)
Precipitation (Adjusted)		
0 ³	0	0
25	+4.70 (11.94)	+3.55 (9.02)
50	+4.50 (11.33)	
100	+8.22 (20.88)	+5.75 (14.60)
400	+12.67 (32.18)	+3.32 (8.43)
1,000		
Percolation		
0 ¹	0	0
25	+3.55 (9.02)	-2.14 (5.44)
86	+4.01 (10.19)	
100	+8.58 (21.79)	-1.84 (4.67)
400	+13.55 (34.42)	+0.43 (1.09)
1,000 ⁴	+11.44 (29.06)	-1.90 (4.83)

¹North - stations 42 and 40 combined; south - stations 47 and 47.7 combined.

²Mean of years 1972-1973.

³North - stations 42 and 40 combined; south - station 47.

⁴Mean of years 1971-1973.

⁵Italicized units in centimeters.

Most snow researchers working in forests have demonstrated that as soon as an opening is created more snow is deposited, except on very windy terrain. As to the reason for more snow, evidence over the years has been conflicting (Anderson and others 1976).

There is a reasonable explanation for little or no real increase in snow beyond 4.0 tree heights and up to 10.0 tree heights on the south aspect. Haupt (1973) concluded that the proximity of the clearcut to the main ridge, with greater exposure of wind and energy, were contributing factors. It was found that prevailing winds scoured snow in the clearings, transported some of it over the ridge, and deposited it in a cornice to the lee of the ridge. In years 1970 and 1971, the cornice accumulated significantly more W.E. by mid-March than would have occurred if the clearings had not existed on the south aspect. Because north aspect stations are located well downslope and slightly upwind, it is unlikely that snow from the south snowpack was moved much beyond the cornice and redeposited there.

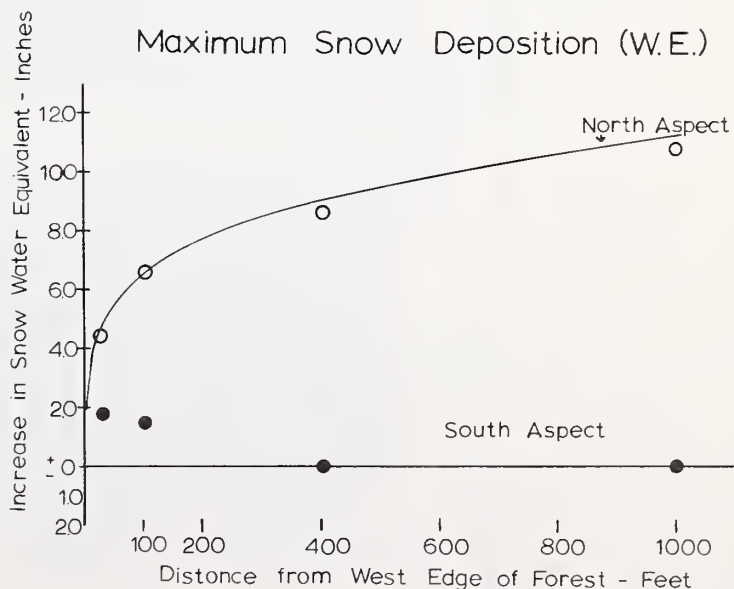
Greater windspeed in the south clearcuts also suggested accelerated evaporation or sublimation losses from the snowpack. By assuming exposure conditions similar to those described by West (1959) for windy locations near ridges, the expected evaporation or sublimation losses (not measured) could have been 1 to 2 inches (2 to 5 cm) greater in the larger clearings than in the north clearings and south forest.

North aspect.--This aspect shows an exponential increase in W.E. with an expansion of the size of the clearing. Average gains up to 10.8 inches (27 cm) occurred in the largest clearing (table 4, figures 7 and 8).

Was on-site redistribution of snow by wind a factor contributing to greater snow deposition in the clearings? This question has been answered affirmatively elsewhere in studies of forest versus clearings in the high elevations of central Colorado. Hoover and Leaf (1967) concluded:

This result (cutting treatment did not increase snow storage)¹ fails to confirm the hypothesis that the increased streamflow after treatment is brought about by decreased interception loss. Our inference from this and the actual difference in snow catch between cut and uncut strips is that while total snow catch remains the same, it is distributed differently over the watershed.

Figure 7.--Maximum snow deposition by aspect. Closed circles represent south stations, open circles represent north stations.



¹Parenthetic expression that of the author.

Snow Water
Equivalent - Inches

North

Prevailing wind →

Clearcut
block - 1000'
186'
(466)

400' block
19.4"

50' strip
15.3"
11.7"

10.3"

200' strip
17.5"

2.116"

Forest
1 mile west
101'
(40)

26

24

22

20

18

16

14

12

10

8

6

4

2

0

(46)

(45)

(44)

(42)

220

180

150

120

90

60

30

0

50

20

10

0

10

20

30

40

50

60

70

80

90

100

110

120

130

140

150

160

170

180

190

200

210

220

230

240

250

260

270

280

290

300

310

320

330

340

350

360

370

380

390

400

410

420

Distance in Feet

South

Snow Water
Equivalent - inches

Prevailing wind

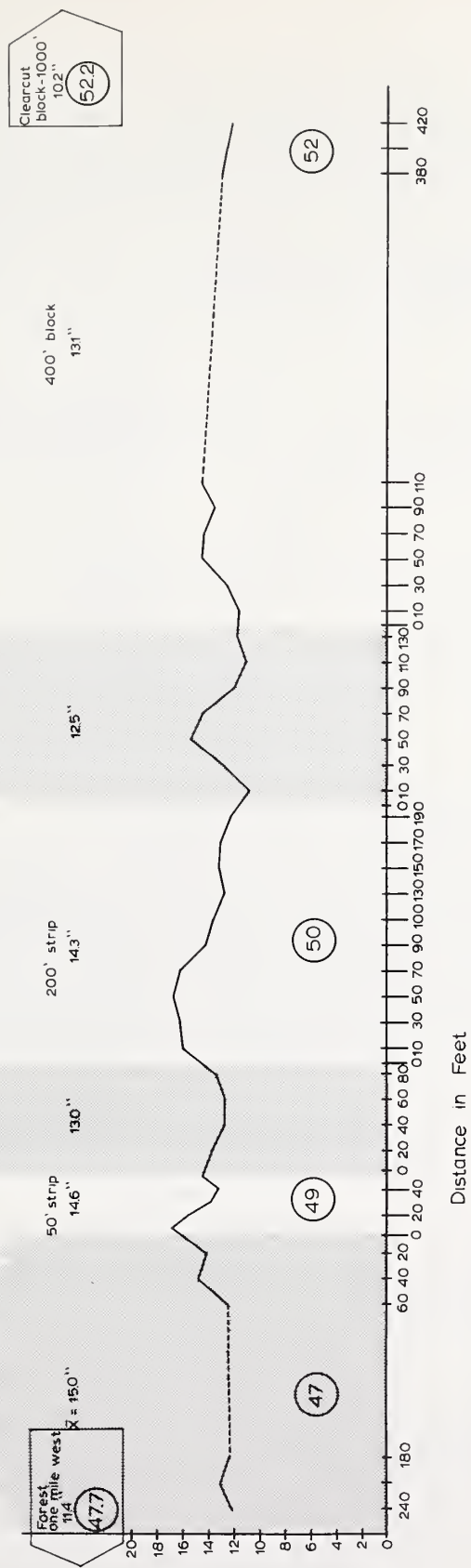


Figure 8.--Maximum snow deposition profile by sampling point for A. north aspect and B. south aspect.

There is less snow held by the forest covered strips and more in the openings than there was before treatment. The reason for this redistribution is the effectiveness of the openings in trapping snow transported from the intervening forested strips. Before cutting, wind action sifted snow through the forest canopy and tended to accumulate it on the ground in numerous, rather evenly distributed, small, natural openings. After cutting, the resultant openings are effective snow traps and the wind stress on the remaining forest canopy is increased. This has caused the removal of some snow that formerly settled in the forested strip to the adjacent open areas.

Other researchers working in Colorado (Dietrich and Meiman 1974; Gary 1974) and in central Sierra Nevada (Smith 1974) support the Hoover-Leaf hypothesis. Gary, in particular, concluded that greater W.E. in a small isolated clearing 1.0 tree height wide by 5.0 tree heights long (35 by 160 ft or 11 by 49 m) must be weighed against decreased W.E. in the adjacent downwind forest.

Our measurements of snow taken at four different locations in the forest (see below) do not support the Hoover-Leaf hypothesis.

Forest-station N40 (T)
[1 mile (1.6 km) upwind
from station N42(T)]

Forest-station N42(T)

Forest leave-strips
No. 1 No. 2

- - - - - *Maximum W. E. inches* - - - - -

10.1
(25.6 cm)

11.6
(28.7 cm)

10.3 11.7
(26.2 cm) (29.7 cm)

Increased wind stress carries snow from canopies close to the forest edge to adjacent openings. If this process were operative, the measurements near the forest edge (station N42(T) and particularly in the narrow, windswept leave-strips (see above and fig. 8) should reflect a sharp decrease. Instead, the three locations have W.E. values in inches comparable to the measurement taken deep in the forest (station N40(T)), 1 mile (1.6 km) upwind and quite removed from the far-distant forest edge near station N42(T). (Variations among the four values shown are considered the normal "noise" for snow measurements taken in the forest.)

Comparison of records in forest and small clearings as well as weekly observations indicate that snow on the more protected north aspect tends to persist on mature trees--sometimes for several weeks. Unlike snow in the higher and colder Colorado Rockies, very little is blown from the canopy. When snow is dislodged, it usually falls to the forest floor in massive wet clumps (Haupt 1972b).

Because the Hoover-Leaf hypothesis does not seem appropriate for Priest River conditions, other processes such as interception loss from evaporation or sublimation of canopy-held snow and wind eddy-forest-edge effects during storms appear to be operative.

Summary.--On the south aspect, buildup in snow W.E. was restricted because of losses by wind scouring and perhaps by evaporation or sublimation. These factors had minimal influence on the north aspect as evidenced by the accumulation of large depths of snow W.E., especially in the wider clearings. The processes influencing this buildup appeared to be different from those in the higher elevation forests of Colorado and California.

Seasonal Precipitation

Early investigators recognized that gage-catch deficiencies were proportional to wind velocity (U.D. Army, Corps of Engineers 1956). The Central Sierra Snow Laboratory developed linear adjustment factors based specifically on mean winter windspeed. These

factors are used to correct wind-related deficiencies at stations in this study (table A3). A reference table showing the factors is included (table B1).

South aspect.--The decline in seasonal precipitation begins 1.0 to 2.0 tree heights downwind. At 4.0 tree heights, total catch is no greater than recorded for the 50-foot (15 m) wide strip (table 4 and fig. 9).

Seasonal Precipitation (adjusted)

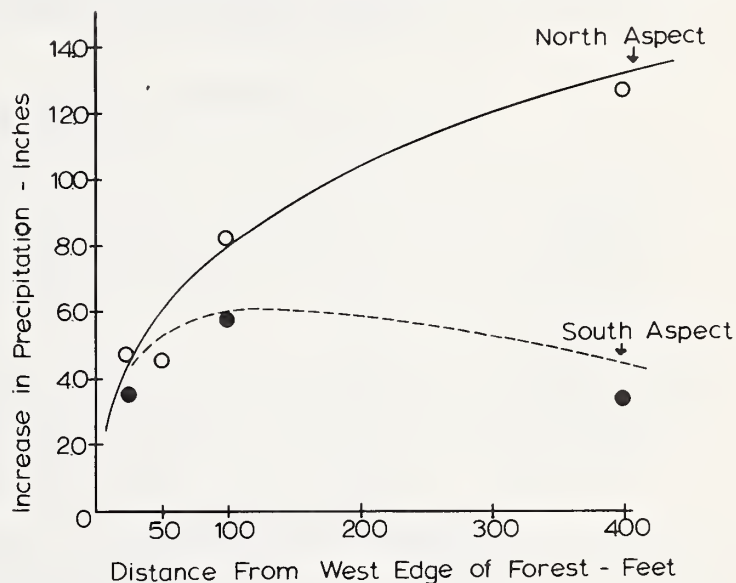


Figure 9.--Seasonal precipitation (adjusted) by aspect. Closed circles represent south stations, open circles represent north stations.

North aspect.--Inspection of the relative gains (table 4) and of the plot of the gains against distance from edge of forest (fig. 9) reveals that the effect of clearing on the north aspect resulted in a positive exponential increase in catch. Increases of more than 13 inches (33 cm) were recorded at distances of 2.7 tree heights from the edge of forest. Although we made no measurements, we assumed that totals would decline beyond 3.0 tree heights. This is suggested by the decrease in percolation measured at lysimeters located beyond 3.0 tree heights.

What factors may be associated with increases in catch? Do these increases result from savings in interception loss and (or) from local wind eddy-forest edge effects during storms as well?

Discussion.--Fedorov and Burov (1967) offered the hypothesis, supported by considerable evidence, that local wind eddy-forest edge effects are important. They developed a rationale for defining an "ideal" clearing of optimum dimensions (in terms of angle of shielding of the horizon) where the most reliable amount of precipitation falls. If the clearing was too large or too small, differences occurred in the amount of precipitation measured.

They reported that the increase in error for clearings of large dimensions (angle of shielding of $<20^\circ$) can be explained by the influence of aerodynamic conditions. This influence is manifested in a slight expansion of the storm-bearing streamlines over such a clearing and in the slowing of the main stream promoting excess precipitation. On the deficit side, the expansion of the streamlines is less pronounced over small clearings with an angle of shielding of greater than 45° . In such clearings during strong winds, snow (or rain) falls at an oblique angle; so part of the precipitation is intercepted by bordering trees and does not enter the receiving surface of a rain gage. Thus, the ideal clearings, where the same amount of precipitation falls as in the surrounding forest, are those that are shielded from the horizon at an angle of 30° to 45° .

The Fedorov-Burov description of ideal clearings agrees with an earlier evaluation of gage exposures conducted by Brown and Peck (1962) in Utah. Brown and Peck subjectively described the best or optimum opening for siting a rain gage, as being "well-protected" or sheltered in all directions (a) by objects subtending angles of 20° to 30° from the gage with none greater than 45° and (b) by objects of sufficient breadth to minimize eddy effects.

The criteria developed by Fedorov and Burov and by Brown and Peck were applied to the north aspect stations as shown:

<i>Station</i>	<i>Angle of shielding of the east and (or) west horizon</i>	<i>Comparison of precipita- tion gains in clearings (Inches)</i>	<i>Comparison of maximum snow deposition (W.E.) gains in clearings (Inches)</i>
N42(0) (forest)	90°	0.0	0.0
N45(0) (clearing)	65°	4.70	4.4
N39(0) (clearing)	49°	4.50	5.6
Ideal→N44(0) (clearing)	42°	8.22	6.6
N46(0) (clearing)	14°	12.67	8.6

The precipitation gains, as well as maximum W.E. gains, correlate reasonably well with the Fedorov-Burov hypothesis: stations N45(0) and N39(0) are apparently overshielded (too little precipitation catch), station N46(0) is undershielded (too much catch), while station N44(0) represents (with some reservations) the "ideal" clearing. Station N44(0), unobstructed by trees on its south boundary, may be undershielded in that direction. Notwithstanding this limitation, and if we assume that precipitation measured in the clearing approximates that falling into the forest, the gain of 8.22 inches (21 cm) may about equal or slightly exceed interception loss associated with old, climax stands (cedar-hemlock habitat type) on north aspects. By expanding this logic, gains registered at stations N45(0) and N39(0) represent an underestimate of interception loss, and the gain observed for station N46(0) includes the increment of interception loss plus an increment of 4 or 5 inches (10 or 13 cm). This last increment may represent excess precipitation caused by wind eddy-forest edge effect during storms.

The snowpack gain of 6.6 inches (17 cm) measured at station N44(0) offers further evidence of the magnitude of interception loss. Likewise, the snowpack gain observed for station N46(0) includes interception loss plus an additional 2 inches (5 cm). The last may represent excessive snow deposition (precipitation). However, the snow gains at stations N44(0) and N46(0) constitute net precipitation and therefore are underestimates compared to gains measured by the precipitation gages. Underestimates resulted from differential losses before April 1 due to winter melt, percolation, and evaporation and sublimation.

The following questions remain: At what point downwind from station N46(0) does deficit precipitation balance excess precipitation? Or, is the excess precipitation at station N46(0) merely the deficit precipitation that did not fall in the large south aspect clearing?

Summary.--Precipitation totals on the south aspect openings declined after 1.0-2.0 tree heights downwind. Precipitation totals on the north aspect increased with distance from the forest edge to at least 3.0 tree heights. There seemed to be an opening of optimal size where the same amount of precipitation fell as fell over the forest.

From 7 to 8 inches (18 to 20 cm) represented the interception loss associated with old climax stands on north aspects. On small clearings, the precipitation catch was deficient by about 4 inches (10 cm), whereas on the large opening the catch gained an excess of about 4 inches (10 cm).

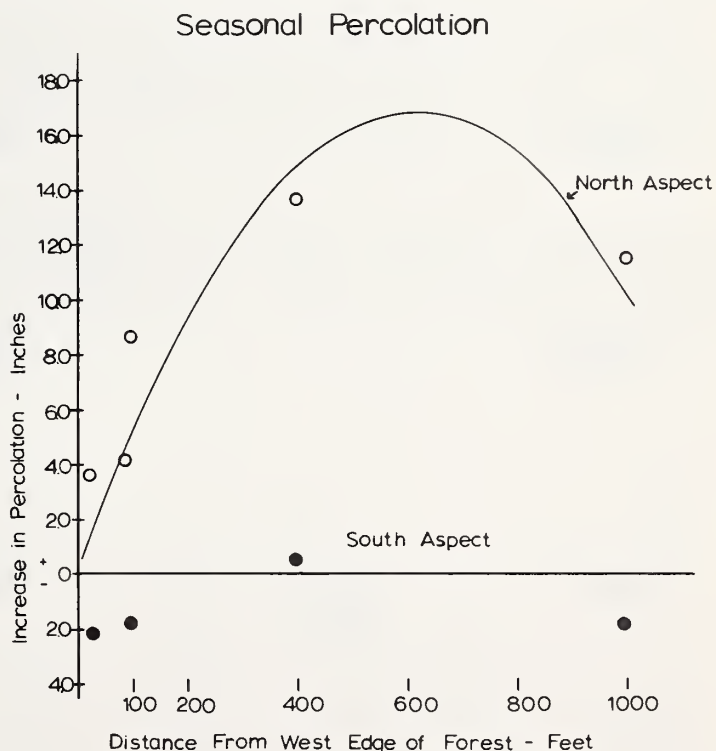
SEASONAL, MONTHLY, HIGHEST DAILY AND MEAN DAILY PERCOLATION

Seasonal Percolation

Percolation measured by the lysimeter represents net precipitation available to infiltrate the soil surface. On the north aspect, the general pattern of percolation gains closely resembles that of precipitation gains, although individual totals are slightly less in smaller openings and slightly greater in the larger openings (table 4). These apparent differences may not be important because correction factors were used to adjust precipitation.

Lysimeter results on the south aspect were totally unlike those on the north aspect (fig. 10). Here seasonal deficits rather than gains were measured for the average year at each station in the clearing except station S52(0), where a small gain occurred. In individual years, there were small increases in other south aspect clearings. In any one year, however, the gain was never greater than 2 inches (8 cm).

Figure 10.--Seasonal percolation by aspect. Closed circles represent south stations, open circles represent north stations.



There are important sources of water loss associated with the larger south-aspect clearings during and between storm periods. These are discussed in detail by Cline and others (1977).

Summary.--The general pattern of seasonal percolation gains due to forest removal was similar to that of precipitation gains (corrected for wind).

Monthly Percolation

Under average conditions, percolation occurred at each station in every month of study (fig. 11). For some individual year-month combinations, snowpack temperatures were too low to permit release of water from the snowpack (appendix C).

In cool winter months--November through February--the snowpack in the north forest usually released more water than the snowpack in the smaller openings (25, 86, and 100 feet or 8, 26, and 30 m wide). Only in large clearings (400 and 1,000 feet or 122 and 305 m wide) was percolation greater. With few exceptions, less water was released from openings on the south aspect than from openings in the forest.

Drip originates in the canopy and contributes to the release of water or percolation in the forest during winter. This phenomenon is more evident tree for tree in the south forest because of the greater influx of energy (Haupt 1972b).

By March, the snowpack melts rapidly in larger clearings, particularly in those on the south aspect. As a consequence, monthly percolation is faster than in the shaded forest (fig. 11).

By April and May, monthly percolation in the large north clearing far outstrips that in the forest because of deeper snowpacks and greater daytime melt. The reverse condition prevails on the south aspect where snow generally disappears in the large clearings by May, but persists in the forest. Consequently, monthly percolation for May is greater in the forest (fig. 11).

Summary.--Water generally drains from the snowpack in every month of the winter. Because of drip contribution from foliage, snowpacks under timber drain more water than snowpacks in the clearings, except in the larger openings on the north aspect. The reverse situation occurs by March on the south aspect and by April on the north aspect: because of greater energy flux, more water drains from clearings than under the forest.

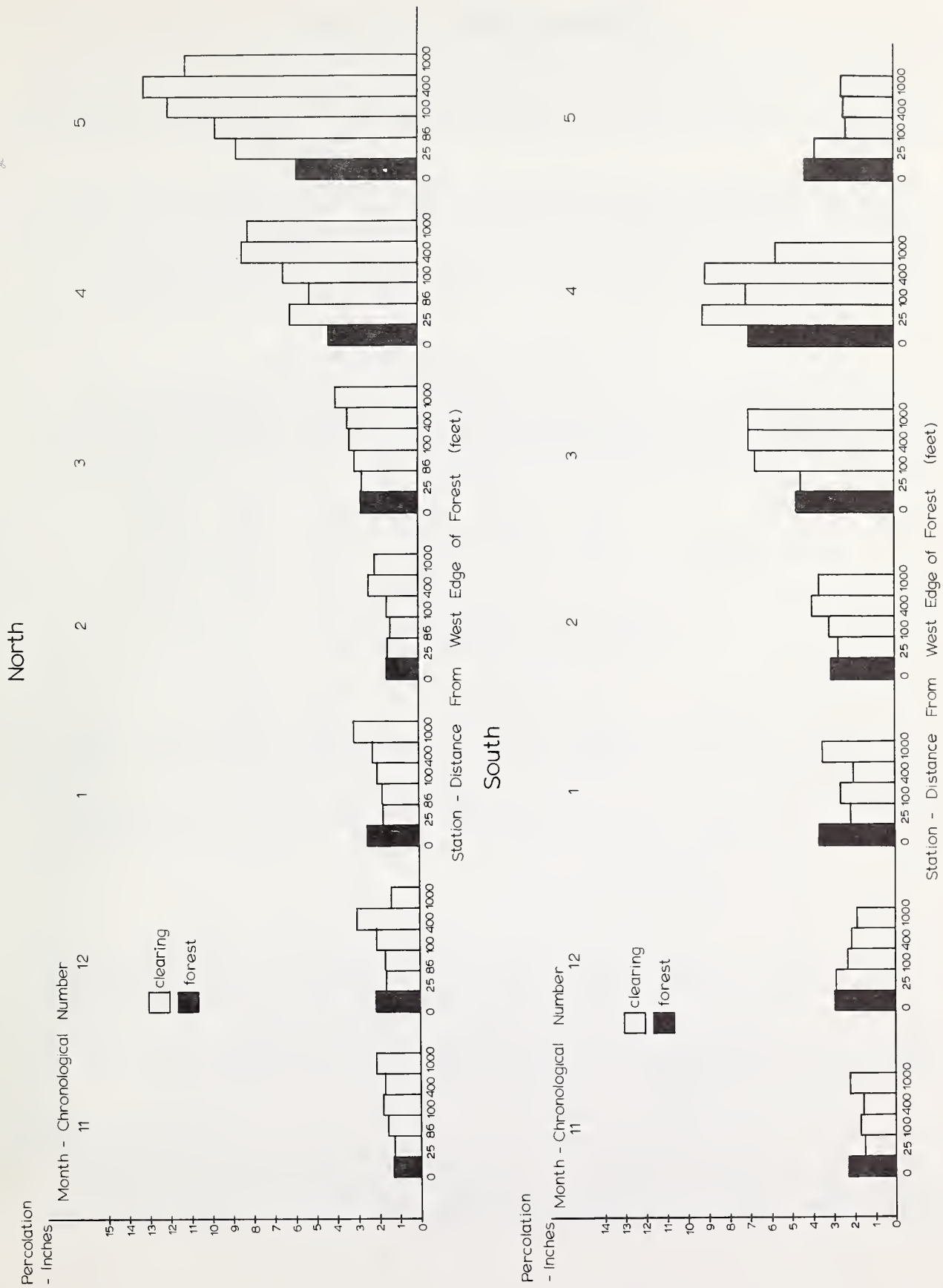


Figure 11.---Monthly percolation for A. north aspect and B. south aspect.

Highest Daily Percolation

Does clear weather snowmelt or rain with snowmelt (rain on snow) produce greater daily totals of percolation in the Experimental Forest? Does the size of clearing have an effect?

For the study period, the 35 highest ranking daily outflows of clear weather snowmelt and of rain with snowmelt on the north aspect and the 28 highest on the south aspect (1 year less of record) were averaged. Stations S52.2(0), S47.7(T), and N46.6(0) were excluded from the analysis because of too few years of data. The highest daily totals for each station event are listed in appendix D, but only the mean values will be discussed (table 5).

Table 5.--Highest daily percolation, in inches

Event	Distance from west edge of forest, in feet					
	400	100	86	25	0 ¹	0 ²
North ³						
Snowmelt	1.40 (3.56) ⁴	1.22 (3.10)	1.05 (2.67)	1.08 (2.74)	0.96 (2.44)	0.68 (1.73)
Rain with snowmelt	1.26 (3.20)	1.02 (2.59)	0.91 (2.31)	1.00 (2.54)	0.91 (2.31)	0.89 (2.26)
n=35						
South ⁵						
Snowmelt	1.10 (2.79)	0.95 (2.41)		0.91 (2.31)	0.98 (2.49)	
Rain with snowmelt	1.16 (2.95)	1.01 (2.57)		0.99 (2.51)	1.23 (3.12)	
n=28						

¹North - station 42; south - station 47.

²North - station 40.

³Years - 1969-1973.

⁴Italicized units in centimeters.

⁵Years - 1970-1973.

North aspect.--Except at station N40(T), the 24-hour daily snowmelt exceeded the 24-hour rain with snowmelt in the forest. This is also true of all stations in the clearings. For both weather events, the relationship was the same: the greater the distance to the middle of a clearing, the greater the daily percolation. This would be expected with snowmelt because of greater energy flux in the larger clearing and with rain with snowmelt because more precipitation falls in the larger clearing.

However, a timing delay contributed to higher snowmelt totals. Normally, the snow-pack persists until late in the season and, therefore, responds to the increased energy flux common to nonrainy periods in late spring. Highest daily snowmelt invariably occurs in the last 6 to 10 days before snow disappears in May. The highest 24-hour totals of rain with snowmelt are associated with warm, rainy storm fronts that move across Idaho in November, December, and January.

South aspect.--The melt picture is more complex. By examining the data from clearings, we find that daily snowmelt increases as the distance from edge of forest increases. However, daily snowmelt in the forest is as great or greater than that in any clearing, except station 52. This high melt rate for the forest follows a time-delay relationship. The snowpack shaded by the forest lasts longer, usually into May, and so may receive a greater energy flux.

On the south aspect, the most elevated, 24-hour total (1.23 inches or 3.12 cm) occurred as rain with snowmelt in the forest. Our lysimeter records indicate that this total includes a large increment of drip, which is associated exclusively with trees.

Based upon per unit of crown projection, the south forest has the capability of producing more percolation in a 24-hour period than the north forest. For openings in general, greater percolation totals can be expected in north clearings than in south clearings.

Summary.--The highest daily percolation rates usually are associated with snowpacks in clearings rather than those under the forest. There is one exception, the south aspect forest. Here the drip contribution can be phenomenally high because the energy flux associated with sunny, windswept slopes is greater than in the forest. Only in the largest clearings on the north slope do daily rates exceed those in the forest on the south aspect.

Mean Daily Percolation

Mean daily percolation was determined by a two-step procedure: the first step was to select a beginning date, time = day 1. For the winter period, time = day 1 was November 1. The second step was to accumulate consecutive days of percolation through February 28 (time = day 120) and then to divide by 120 to calculate the mean daily rate. For the spring period, time = day 1 was March 1 and the mean daily rate was based upon the number of days up to and including the final day of melt. Mean rate by year, aspect, and station are listed under appendix E; table 6 displays mean rates for combined years 1971-73.

On both aspects, from November 1 through February 28 mean rates in the forest equaled or exceeded those in the clearings except for north station N46(0). The high mean rate in the forest was due primarily to the drip component. After March 1, the percolation rate pattern reversed; rates in the clearing equaled or exceeded those in the forest because of more exposure to energy sources.

Table 6 shows April 6 in the average year as the last day that snow was present at all stations. Mean rates on April 6 were greater at each location on the south aspect than on the north aspect. This relationship held whenever the snowpack was on both aspects. (A comparison of the means of two different stations must be calculated the same day to be valid.)

After March 1 mean percolation rates in all but one of the clearings surpassed those of the forest as long as snow remained in the clearing and forest. The exception, north station N39(0), sometimes had rates no greater than those in the adjacent forest, which suggests that the wind and the shading effect kept melting to a minimum.

Table 6. --Mean daily percolation during winter and spring periods, in inches, for years 1971-73

Season/date	Distance from west edge of forest												
	1,000	400	100	25	0 ¹	0 ²	1,000	400	100	86	25	0 ¹	0 ²
SOUTH													
Winter													
November 1													
through													
February 28	0.09	0.08	0.09	0.08	0.11	0.10	0.07	0.09	0.07	0.06	0.06	0.07	0.07
Spring													
March 1													
through:													
April 6	.29	.31	.28	.21	.24	.17	.14	.14	.14	.13	.12	.11	.12
7	Bare		Bare										
10		.35		.24	.26	.18	.16	.16	.15	.12	.14	.12	.13
11		Bare											
18				.26	.25	.18	.15	.15	.15	.12	.13	.12	.12
19					Bare								
20				.27	.19	.19	.15	.15	.14	.12	.14	.12	.12
21				Bare									
26						.23	.18	.19	.17	.14	.16	.13	.13
27						Bare							
29							.20	.23	.19	.16	.19	.15	.15
30													Bare
May							.25	.27	.22	.18	.22	.18	.18
2												Bare	
3							.25	.27	.23	.19	.23		
4													
5							.25	.27	.23	.19	.23	Bare	
7							.28	.29	.26	.21			
8							.29	.31	.26	Bare			
9							.29	Bare	.27				
10													
11							.29						
12							Bare						

¹South - station 47; north - station 42.
²South - station 47.7; north - station 40.

Summary.--On snow-covered north and south aspects, mean daily percolation rates are always greater on south slopes regardless of the degree of forest removal. Small, well-protected clearings on the north aspect do not increase mean daily rates significantly over those in the surrounding forest.

Snow Disappearance

Ground surface became bare of snow earliest in the larger south aspect clearings (table 6) some 7 to 11 days after April 1 (table 7). Snow melted in the south forest an average of 10 to 16 days later. Early snowmelt in the clearings resulted from (a) lack of a deep snowpack at the beginning of melt and (b) higher average melt (or percolation) rates than those in the forest.

Table 7.--Mean elapsed days after April 1 before snow disappearance in lysimeters, years 1971-73

Slope	Distance from west edge of forest, in feet						
	: 1,000	: 400	: 100	: 86	: 25	: 0 ¹	: 0 ²
South	7	11	7		21	19	27
North	42	39	40	38	35	33	30

¹North - station 42; south - station 47.

²North - station 40; south - station 47.7.

In sharp contrast, a much deeper snowpack had been deposited in the north clearings by the start of spring melt. In spite of higher melt rates, north clearings usually kept their snow covering 2 to 12 days longer than the forest floor.

A comparison of stations S47(T) and S47.7(T) in the south forest showed that 47.7, the more shaded of the two, kept its snow 8 days longer. In the north forest, canopies over stations N42(T) and N40(T) were nearly alike. However, station 40 was approximately 300 feet (91 m) lower in altitude which may explain why snow disappeared 3 days later at the higher station (table 7).

Summary.--Generally, the greater the distance from the edge of forest the later snow persisted on the north aspect and the sooner it disappeared on the south aspect. Also, the denser the forest cover on the south aspect, the longer the snow cover remained.

SNOW DEPTH, SNOW DENSITY AND BIG GAME MOBILITY

Winter represents the critical time of year for big game because snow can severely hinder animals searching for shelter and forage. Big game biologists claim two properties of the snowpack--depth and density (hardness)--are of paramount influence. Table 8 shows approximate threshold depths of soft snow at which mobility becomes difficult for the four major big game animals of northern Idaho. Note that moose can move about in twice the depth of snow as the lithe, fleet-footed mule deer.

As the snow density increases so does the mobility problem. Nasimovich (1955) described in considerable detail the effect of various snow densities. For instance, if snow is loose and powdery with low densities ranging between 0.15 and 0.20, large mammals can run without difficulty in greater depths than those shown in table 8. If the densities are in the 0.21 to 0.22 range, snow impedes the animals' movements. If densities range between 0.24 and 0.26, animals do not sink as far into the snow, but it is more difficult for them to lift their feet from the hole in the snow to take another step.

Snow of very high density (crustiness) can also hinder the animal in moving about, according to Kelsall and Prescott (1971). Many crusts are hard enough to support walking animals and some, but not all, do so. Animals that break through can lacerate their feet and legs on sharp edges.

Table 8.--*Approximate depth of soft snow when mobility becomes difficult for large mammals*

Mammal	Snow depth threshold	Literature reference
<i>Inches</i>		
Mule deer	18	Gilbert and others 1970
Moose	37	Nasimovich 1955
Caribou	24	Pruitt 1959
Elk	22 ¹	Kelsall and Telfer 1971; Kelsall 1969

¹Calculated from analogous data.

When snow is deepest in the Priest River study area, large mammals would find the going impossible on the north aspect, especially in clearings. In winters such as 1973, when snowfall is low, it might be feasible for them to move through the forest (table 9). Mobility here would be easier with the slightly lower densities associated with the shallow 1973 snowpack (table 10).

On the average, conditions on the south aspect are slightly better, but only in years of low snowfall, such as 1973. In such winters, the large, windswept opening as well as the forest sites offer more favorable snow depths. However, densities would be high and the excessive crustiness associated with south exposures might be impeding.

Early melt is a south-aspect attribute. The large south-aspect clearing melts soonest and so shrub forage appears much earlier there than on other sites.

Table 9.--Greatest snow depth and approximate day of its occurrence on north and south aspects

Aspect/ year	Approximate day of occurrence	Distance from west edge of forest, in feet						
		1,000	400	100	50	25	0 ¹	0 ²
<i>Inches</i>								
<u>North</u>								
1970	3/25		63	61	58	54	45	44
1971	4/1		57	56	55	47	39	29
1972	3/2	56	60	54	50	53	43	31
1973	3/15	54	45	42	33	34	17	14
$\bar{M}$	3/19	55 (1.4 m)	56 (1.4 m)	53 (1.3 m)	49 (1.2 m)	47 (1.2 m)	36 (0.9 m)	30 (0.8 m)
<u>South</u>								
1970	3/18		38	44		47	48	
1971	3/17		46	45		52	47	
1972	2/17	40	44	47		49	46	44
1973	2/22	28	29	31		29	27	18
$\bar{M}$	3/4	34 (0.9 m)	39 (1.0 m)	42 (1.1 m)		44 (1.1 m)	42 (1.1 m)	31 (0.8 m)

¹North - station 42; south - station 47.

²North - station 40; south - station 47.7.

Table 10.--Snow density at greatest depth on north and south aspects

Aspect/year	Distance from west edge of forest, in feet						
	1,000	400	100	50	25	0 ¹	0 ²
<u>North</u>							
1970		0.35	0.34	0.33	0.34	0.35	0.33
1971		.36	.35	.34	.34	.35	.38
1972	0.34	.34	.32	.33	.31	.30	.32
1973	.35	.33	.30	.34	.30	.32	.34
$\bar{M}$	.34	.34	.33	.34	.32	.33	.34
<u>South</u>							
1970		.37	.34		.35	.33	
1971		.32	.35		.33	.32	
1972	.30	.31	.33		.32	.31	.33
1973	.29	.33	.33		.29	.27	.26
$\bar{M}$	.30	.33	.34		.32	.31	.30

¹North - station 42; south - station 47.

²North - station 40; south - station 47.7.

Summary.--The winter mobility of big game mammals is greatly impeded by deep snow in forest clearings. Ranked by relative mobility are the following: mule deer < elk < caribou < moose, the last being the most capable of moving about in deeper snow. Very high density snow (crustiness) may greatly hinder movement and in some cases injure the feet and legs of animals. Windswept openings on south aspects are bare earlier in the spring and can provide much sought-after forage.

MANAGEMENT CONSIDERATIONS

Some management considerations drawn from the results of the study are listed below. Potential users should be aware that these considerations were developed from a limited amount of data, from more unreplicated than replicated stations in two climax habitat types, and under the sequence of climatic events recorded. Any extrapolation should be done with these limitations in mind.

Creating larger openings on the north aspect will develop a high potential for increasing total water yield. On the south aspect, similar clearings located in a slope position below the ridge crest will have a minimal or even a negative effect on water yield increase.

Winter flooding caused by rain with snowmelt will be enhanced by creating larger openings on the north aspect. Because of the copious amounts of drip associated with south-aspect forests, any clearing in these forests will lessen the hazard of winter flooding.

Because of greater snow deposition and higher melt rates, large openings on the north aspect can cause higher spring peak flows for many years after logging, thus imperiling water quality. This hazard can be greatly reduced by using very small, well-shielded openings.

Larger openings on the south aspect permit a more rapid spring melt and an earlier disappearance of snow than occur in the uncut forest. In theory, by maintaining a balance between the amount of area cut and that left uncut, peak flows from a south-facing watershed would be reduced because of desynchronization of melt rates.

Big game winter range will not be enhanced by clearing old stands on the north aspect. Openings on the south aspect will benefit big game because of the early appearance of shrub forage in the springtime.

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APPENDIX A

Mean seasonal windspeed table A1, maximum snow deposition table A2, seasonal precipitation table A3, and seasonal percolation table A4

Table A1.--Mean seasonal windspeed for each year of study

Aspect and year	Distance from west edge of forest, in feet					
	400	100	50	25	0 ¹	0 ²
----- Feet second ⁻¹ -----						
North						
1969	3.4	2.5	1.2	1.9	³	0.7
1970	3.9	2.5	1.4	2.2	³	1.3
1971	4.3	3.0	1.5	2.5	1.8	1.0
1972	5.7	2.8	0.9	3.1	1.5	³
1973	4.6	2.5	³	2.6	1.5	³
South						
1970	5.3	4.9		4.3	2.4	
1971	6.4	6.2		5.0	3.1	
1972	7.2	6.1		5.2	3.2	
1973	6.2	5.0		4.3	1.4	

Table A2.--Maximum snow deposition for years of study

Aspect and year	Distance from west edge of forest, in feet						
	1,000	400	100	50	25	0 ¹	0 ²
----- Inches -----							
North							
1969		24.6	22.9	21.6	19.0	17.0	18.0
1970		22.5	20.6	19.0	18.0	15.4	14.7
1971		20.2	19.3	18.5	16.1	13.5	10.8
1972	19.0	20.2	17.4	16.7	16.5	12.3	10.1
1973	18.6	14.5	12.5	11.4	10.6	5.1	4.7
M	18.8	19.4	17.5	16.4	15.3	11.6	10.1
cm		(49.3)	(44.5)	(41.7)	(38.9)	(29.5)	(25.7)
South							
1970		14.2	15.6		16.7	15.4	
1971		15.2	15.5		17.3	15.2	
1972	12.2	13.7	15.8		15.6	14.4	14.2
1973	8.2	9.3	10.4		8.8	7.2	4.6
M	10.2	13.1	14.3		14.6	13.0	9.4
cm	(25.9)	(33.3)	(36.3)		(37.1)	(33.0)	(23.9)

¹North - station 42

South - station 47.

²North - station 40

South - station 47.7.

³Anemometer inoperative much of year

Table A3.---Seasonal precipitation (actual and adjusted) for years of study, in inches

Aspect and year	Distance from west edge of forest, in feet											
	400	100	50	25	0 ¹	0 ²	400	100	50	25	0 ¹	0 ²
	(Gage catch)						(Gage catch adjusted for wind)					
North												
1969	34.58	32.94	33.61	30.48	28.69	27.98	39.42	36.30	34.62	32.49	30.07	28.40
1970	27.87	26.10	25.36	24.70	21.71	20.55	32.89	28.76	26.12	26.77	22.75	21.17
1971	32.94	32.98	31.45	28.35	28.59	25.19	39.53	36.94	32.39	31.24	30.48	25.76
1972	32.97	31.79	29.92	28.58	26.25	22.92	42.86	35.60	30.59	32.01	27.04	23.61
1973	24.43	23.98	22.61	21.05	19.47	17.44	29.80	25.99	23.29	23.20	20.05	17.96
M	29.55	28.71	27.34	25.67	24.00	21.52	36.27	31.82	28.10	28.30	25.08	22.12
cm	(75.06)(72.92)(69.44)(65.20)(60.96)(54.66)						(92.13)(80.82)(71.37)(71.88)(73.70)(56.18)					
South												
1970	13.12 ³	13.50 ³	13.94 ³	18.87 ³			21.81 ⁴	24.79 ⁴		23.20 ⁴	20.46 ⁴	
1971	21.38	24.68	23.87	25.33			28.26	32.63		29.60	28.37	
1972	22.23	24.78	24.41	22.01			30.86	32.76		30.76	25.09	
1973	17.90	19.45	18.29	16.89			23.66	24.12		21.95	17.40	
M	18.66	20.60	20.13	20.78			26.15	28.58		26.38	22.83	
cm	(47.40)(52.32)(51.13)(52.78)						(66.42)(72.59)(67.01)(57.99)					

¹North - station 42

South - station 47.

²North - station 40

South - station 47.7.

³Modified (July 1970) tilted windshield and stereo orifice.

⁴Adjustment factor for modified shield-orifice = 0.81.

Table A4.--Seasonal percolation for years of study

Aspect and year		Distance from west edge of forest, in feet						
		1,000	400	100	86	25	0 ¹	0 ²
		----- Inches -----						
North								
1969			40.64	35.78	31.91	32.55	33.39	28.62
1970			32.25	26.86	23.60	22.51	20.63	19.93
1971		37.09	39.57	33.23	26.62	29.64	24.90	22.47
1972		32.69	37.71	32.94	26.79	26.60	24.00	22.52
1973		26.01	26.42	23.05	20.80	17.22	15.32	13.73
M		31.93	33.99	29.02	24.45	23.99	21.21	19.66
	cm	(81.10)	(86.33)	(73.71)	(62.10)	(60.93)	(53.87)	(49.94)
South								
1970			28.17	27.36		24.68	25.93	
1971		29.90	34.12	27.61		30.83	33.13	32.37
1972		28.38	29.41	27.33		28.90	32.61	31.19
1973		21.08	21.00	21.30		17.98	20.16	20.62
M		26.45	28.18	25.90		25.60	27.96	28.06
	cm	(67.18)	(71.58)	(65.79)		(65.02)	(71.02)	(71.27)

¹North - station 42

South - station 47.

²North - station 40

South - station 47.7.

APPENDIX B

Gage Deficiency

Table B1.--*Correction factors and gage-catch deficiencies for various mean windspeeds, after Corps of Engineers, 1956*

Mean windspeed (meters second ⁻¹)	:	Adjustment factor	:	Gage deficiency in percent of "true" catch
0	:	1.000	:	0
0.1	:	1.008	:	0.8
0.2	:	1.015	:	1.5
0.3	:	1.023	:	2
0.4	:	1.03	:	3
0.5	:	1.05	:	5
0.6	:	1.07	:	7
0.7	:	1.08	:	8
0.8	:	1.10	:	9
0.9	:	1.12	:	11
1.0	:	1.14	:	12
1.1	:	1.16	:	14
1.2	:	1.18	:	15
1.3	:	1.20	:	17
1.4	:	1.22	:	18
1.5	:	1.24	:	19
1.6	:	1.26	:	21
1.7	:	1.28	:	22
1.8	:	1.30	:	23
1.9	:	1.32	:	24
2.0	:	1.34	:	25
2.1	:	1.37	:	27
2.2	:	1.39	:	28
2.3	:	1.41	:	29
2.4	:	1.43	:	30
2.5	:	1.46	:	31
2.6	:	1.48	:	32
2.7	:	1.50	:	33

APPENDIX C

Monthly Percolation

Table C1.--Monthly percolation,¹ north aspect, in inches

Year	: November	: December	: January	: February	: March	: April	: May
1,000 feet (station 46.6)							
1971	1.78	2.39	5.43	2.74	0.18	11.45	13.12
72	3.39	0.00	1.38	2.78	7.19	4.65	13.10
73	1.31	1.82	2.62	0.65	4.27	8.39	6.95
M	2.16	1.40	3.14	2.06	3.88	8.16	11.06
cm	(5.49)	(3.56)	(7.98)	(5.23)	(9.86)	(20.73)	(28.09)
400 feet (station 46)							
1969	4.62	2.03	0.02	0.26	2.97	16.91	13.83
70	0.94	2.73	1.11	0.34	0.97	5.46	20.70
71	2.08	3.50	4.61	3.05	0.53	13.79	12.01
72	2.75	0.07	1.93	5.73	8.78	5.73	12.72
73	1.12	5.84	1.27	0.50	2.25	8.65	6.79
M	1.72	3.04	2.23	2.40	3.38	8.41	13.06
cm	(4.37)	(7.72)	(5.66)	(6.10)	(8.59)	(21.36)	(33.17)
100 feet (station 44)							
1969	3.64	2.05	0.02	0.00	2.49	14.22	13.36
70	0.91	2.10	0.76	0.16	0.69	4.21	18.03
71	1.90	2.31	4.34	2.01	0.36	10.20	12.11
72	3.11	0.01	2.08	3.45	9.64	3.02	11.63
73	1.27	3.76	0.91	0.63	2.30	8.26	5.92
M	1.80	2.04	2.02	1.56	3.25	6.42	11.92
cm	(4.57)	(5.18)	(5.13)	(3.96)	(5.79)	(16.31)	(30.28)
86 feet (station 39)							
1969	3.51	1.65	0.07	0.17	2.30	13.97	10.24
70	1.00	1.39	0.55	0.34	0.78	3.35	16.19
71	1.63	2.30	3.42	2.26	0.50	6.80	9.71
72	2.54	0.08	1.76	2.07	7.96	2.71	9.67
73	1.25	3.68	1.42	0.72	2.88	7.85	3.00
M	1.60	1.86	1.79	1.35	3.03	5.18	9.64
cm	(4.06)	(4.72)	(4.55)	(3.43)	(7.70)	(13.16)	(24.49)
25 feet (station 45)							
1969	3.47	1.97	0.13	0.02	2.68	13.11	10.90
70	0.77	1.75	0.52	0.30	0.64	3.30	15.23
71	1.33	2.25	3.58	2.11	0.36	11.22	8.77
72	2.07	0.06	1.84	3.06	8.81	3.05	7.71
73	1.05	3.31	1.08	0.71	1.07	7.05	2.95
M	1.30	1.84	1.76	1.54	2.72	6.16	8.66
cm	(3.30)	(4.67)	(4.47)	(3.91)	(6.91)	(15.65)	(22.00)
0 feet (station 42)							
1969	3.62	2.93	0.23	0.36	2.77	13.02	10.46
70	0.62	2.63	1.58	0.65	0.77	2.49	11.89
71	1.56	2.42	3.68	1.81	0.48	7.88	7.07
72	1.75	0.16	2.35	2.95	7.31	3.18	6.30
73	0.92	3.80	2.07	0.90	1.41	4.39	1.83
M	1.21	2.25	2.42	1.58	2.49	4.48	6.77
cm	(1.01)	(5.72)	(6.15)	(4.01)	(6.32)	(11.38)	(17.20)
0 feet (station 40)							
1969	4.11	2.00	0.25	0.34	2.74	13.55	5.63
70	0.83	2.25	1.44	0.76	1.41	2.87	10.37
71	1.64	2.50	4.28	2.00	0.62	8.40	3.03
72	1.77	0.64	2.05	2.53	8.14	4.09	3.30
73	1.46	3.03	3.01	0.96	1.74	1.29	2.24
M	1.42	2.10	2.70	1.56	2.98	4.16	4.74
cm	(3.61)	(5.33)	(6.86)	(3.96)	(7.57)	(10.57)	(12.04)

¹Means exclude 1969.

Table C2.--*Monthly percolation, south aspect, in inches*

Year	: November	: December	: January	: February	: March	: April	: May
1,000 feet (station 52.2)							
1971	2.06	3.12	5.36	3.06	3.03	11.02	2.25
72	3.40	0.35	2.50	4.88	11.61	3.11	2.53
73	1.33	2.07	2.68	3.02	6.35	2.97	2.66
M	2.26	1.85	3.51	3.65	7.00	5.70	2.48
cm	(5.74)	(4.70)	(8.92)	(9.27)	(17.78)	(14.48)	(6.30)
400 feet (station 52)							
1970	0.61	4.01	0.39	4.36	7.63	9.13	2.04
71	1.89	2.77	4.65	3.10	1.51	17.94	2.26
72	2.58	0.07	2.05	6.01	12.84	3.39	2.47
73	1.22	1.79	0.93	2.46	5.94	5.76	2.90
M	1.58	2.16	2.00	3.98	6.98	9.06	2.42
cm	(4.01)	(5.49)	(5.08)	(10.11)	(17.73)	(23.01)	(6.15)
100 feet (station 50)							
1970	0.80	3.12	0.42	2.73	6.86	11.53	1.90
71	2.02	3.06	5.71	2.82	2.27	9.49	2.24
72	2.61	0.23	2.61	4.33	11.53	3.47	2.55
73	1.40	2.78	1.75	2.78	6.00	3.94	2.65
M	1.71	2.30	2.62	3.16	6.66	7.11	2.34
cm	(4.34)	(5.84)	(6.65)	(8.03)	(16.92)	(18.06)	(5.94)
25 feet (station 49)							
1970	0.71	1.89	0.78	1.74	3.22	8.45	7.89
71	1.61	2.75	4.76	2.14	2.06	15.46	2.05
72	2.31	0.12	2.29	4.98	9.39	7.28	2.53
73	1.33	1.99	0.86	1.95	3.48	5.63	2.74
M	1.49	2.88	2.17	2.70	4.54	9.20	3.80
cm	(3.78)	(7.32)	(5.51)	(6.86)	(11.53)	(23.37)	(9.65)
0 feet (station 47)							
1970	0.84	3.88	2.23	1.50	2.02	6.77	8.69
71	3.01	3.47	6.66	2.99	1.48	12.97	2.55
72	3.28	0.08	3.09	5.60	11.73	5.70	3.13
73	1.69	4.35	2.94	1.51	4.09	3.24	2.34
M	2.20	2.94	3.73	2.90	4.83	7.17	4.18
cm	(5.59)	(7.47)	(9.47)	(7.37)	(12.27)	(18.21)	(10.62)
0 feet (station 47.7)							
72	2.20	0.13	2.80	5.39	10.22	5.57	4.88
73	2.15	4.58	3.65	1.36	2.70	4.11	2.07
M	2.35	2.95	3.64	3.28	4.60	6.78	4.46
cm	(5.97)	(7.49)	(9.25)	(8.33)	(11.68)	(17.22)	(11.33)

2

APPENDIX D

Highest Daily Amounts of Percolation

Table D1.--Highest daily percolation from clear weather melt on north aspect for
years 1969-73, in inches

Distance from west edge of forest										
400	:	100	:	86	:	25	:	0 ¹	:	0 ²
2.05		1.97		1.84		1.83		1.98		1.51
2.02		1.89		1.76		1.81		1.84		1.35
2.01		1.80		1.63		1.81		1.65		1.09
1.93		1.57		1.63		1.64		1.57		1.07
1.81		1.50		1.46		1.60		1.38		0.95
1.79		1.47		1.42		1.56		1.34		.89
1.76		1.46		1.29		1.53		1.22		.86
1.68		1.44		1.25		1.42		1.22		.81
1.62		1.43		1.21		1.34		1.19		.80
1.61		1.43		1.09		1.30		1.18		.80
1.59		1.42		1.08		1.30		1.08		.79
1.56		1.35		1.08		1.27		1.02		.78
1.56		1.32		1.03		1.25		1.01		.76
1.47		1.31		1.03		1.21		0.94		.67
1.46		1.26		1.03		1.04		.93		.64
1.45		1.24		1.02		1.03		.89		.60
1.44		1.22		1.01		1.00		.88		.58
1.41		1.21		1.01		0.95		.82		.57
1.39		1.20		0.95		.87		.82		.57
1.38		1.20		.94		.86		.78		.56
1.33		1.16		.92		.85		.76		.54
1.25		1.12		.91		.84		.75		.53
1.21		1.05		.88		.84		.75		.52
1.19		1.01		.87		.80		.73		.52
1.12		0.98		.87		.75		.71		.52
1.05		.98		.85		.75		.71		.50
1.00		.93		.85		.74		.68		.50
1.00		.92		.81		.73		.67		.47
0.98		.91		.80		.70		.64		.46
.98		.89		.77		.70		.63		.46
.96		.87		.75		.69		.61		.45
.96		.86		.71		.68		.61		.45
.95		.80		.70		.68		.56		.45
.95		.83		.70		.66		.55		.45
.92		.79		.66		.64		.54		.40

n = 35

¹Station 42

²Station 40

Table D2.--*Highest days of percolation from rain and snowmelt on north aspect for years 1969-73, in inches*

Distance from west edge of forest										
400	:	100	:	86	:	25	:	0 ¹	:	0 ²
2.06		1.83		1.98		1.81		1.94		1.81
2.01		1.78		1.47		1.77		1.77		1.76
1.91		1.72		1.47		1.67		1.70		1.60
1.79		1.71		1.41		1.65		1.38		1.48
1.73		1.47		1.33		1.39		1.29		1.22
1.68		1.44		1.27		1.31		1.24		1.22
1.59		1.34		1.20		1.29		1.24		1.19
1.50		1.32		1.11		1.27		1.21		1.08
1.49		1.32		1.06		1.24		1.14		0.98
1.48		1.30		1.05		1.16		1.08		.95
1.40		1.27		1.02		1.16		1.02		.91
1.39		1.02		1.00		1.10		1.02		.88
1.36		1.00		0.96		1.02		1.02		.85
1.33		0.94		.91		1.01		0.98		.84
1.28		.94		.88		1.01		.91		.84
1.27		.92		.83		0.92		.85		.81
1.24		.85		.82		.89		.77		.80
1.22		.85		.80		.87		.75		.80
1.18		.83		.80		.85		.74		.79
1.16		.83		.77		.85		.74		.77
1.15		.81		.75		.80		.70		.76
1.09		.81		.70		.78		.68		.74
1.06		.81		.69		.78		.67		.74
1.05		.80		.67		.76		.65		.73
1.05		.80		.66		.74		.64		.68
1.00		.79		.65		.72		.63		.65
0.93		.78		.65		.70		.62		.63
.93		.78		.64		.70		.61		.62
.90		.74		.63		.69		.61		.61
.89		.69		.62		.67		.57		.60
.84		.69		.62		.66		.56		.60
.83		.69		.62		.66		.54		.58
.83		.67		.60		.66		.50		.56
.82		.67		.57		.65		.49		.56
.82		.65		.55		.65		.48		.56

n = 35

¹Station 42

²Station 40

Table D3.--Highest days of percolation from clear weather melt on south aspect for years 1970-73, in inches

Distance from west edge of forest						
400	:	100	:	25	:	0 ¹
1.91		1.97		1.73		2.31
1.86		1.68		1.51		1.64
1.78		1.46		1.37		1.55
1.70		1.34		1.35		1.50
1.44		1.17		1.31		1.28
1.43		1.12		1.20		1.24
1.41		1.06		1.14		1.17
1.41		1.05		1.07		1.15
1.41		1.01		0.98		1.06
1.23		0.98		.95		1.00
1.23		.97		.89		0.96
1.20		.87		.87		.92
1.16		.87		.86		.89
1.07		.85		.80		.88
1.06		.83		.78		.85
0.86		.83		.78		.81
.85		.81		.78		.77
.83		.79		.76		.77
.80		.76		.76		.75
.78		.74		.76		.73
.76		.73		.69		.73
.75		.73		.67		.71
.74		.73		.66		.70
.66		.72		.60		.67
.64		.70		.59		.62
.61		.66		.58		.61
.61		.62		.56		.55
.59		.62		.54		.55

n = 28

¹Station 47

Table D4.--Highest days of percolation from rain and snowmelt on south aspect for years 1970-73, in inches

Distance from west edge of forest						
400	:	100	:	25	:	0 ¹
2.21		2.43		2.02		2.41
2.21		2.26		1.88		2.10
2.15		1.89		1.84		2.09
1.84		1.61		1.48		1.97
1.75		1.61		1.43		1.80
1.73		1.57		1.42		1.76
1.64		1.44		1.40		1.69
1.43		1.33		1.37		1.58
1.40		1.05		1.29		1.40
1.30		1.02		1.15		1.34
1.25		0.95		1.05		1.26
1.24		.91		1.03		1.16
1.18		.86		0.99		1.10
1.15		.81		.94		1.04
1.10		.77		.84		0.97
1.08		.75		.82		.96
0.79		.72		.75		.93
.78		.68		.71		.92
.77		.68		.60		.90
.76		.63		.55		.86
.74		.62		.54		.84
.63		.57		.53		.84
.60		.57		.52		.84
.59		.55		.52		.81
.57		.55		.52		.78
.55		.54		.50		.74
.55		.52		.50		.73
.53		.52		.46		.72

n = 28

¹Station 47

APPENDIX E

Mean Daily Percolation Rates

Table E.--Mean daily percolation during winter and spring periods on north slope,
in inches

Date	Distance from west edge of forest, in feet						
	1,000	400	100	86	25	0 ¹	0 ²
<u>1969</u>							
Nov. 1-Feb. 28	0.06	0.05	0.04	0.05	0.06	0.06	
Mar. 1-31	.10	.08	.07	.09	.09	.09	
April 30	.33	.27	.27	.26	.26	.27	
May 7	.38	.32	.30	.29	.30	.29	
8							bare
10	.44	.37	.34	.34	.34		
11	bare	.38	bare	bare	bare		
12		bare					
<u>1970</u>							
Nov. 1-Feb. 28	0.04	0.03	0.03	0.03	0.05	0.04	
Mar. 1-31	.03	.02	.03	.02	.02	.05	
April 30	.11	.08	.07	.06	.05	.07	
May 16	.29	.24	.22	.22	.18	.18	
17							bare
18	.31	.26	.24	.23	.19		
19	.32	.27	.25	bare	bare		
20	.33	.27	bare				
21	bare	bare					
<u>1971</u>							
Nov. 1-Feb. 28	0.10	0.11	0.09	0.08	0.08	0.08	0.09
Mar. 1-31	.01	.02	.01	.02	.01	.02	.02
April 30	.19	.23	.17	.12	.19	.14	.15
May 2	.23	.28	.21	.15	.23	.16	.16
3							bare
5	.29	.33	.25	.18	.27	.20	
6	.31	.35	.26	.19	bare	.20	
7	.32	bare	.29	.21			
8	.31	bare	.29	.21			
9			.29	bare			
10			bare				
<u>1972</u>							
Nov. 1-Feb. 28	0.06	0.09	0.07	0.05	0.06	0.12	0.06
Mar. 1-31	.23	.28	.31	.26	.28	.24	.26
April 30	.19	.24	.21	.17	.19	.17	.20
May 3	.21	.26	.22	.19	.21	.18	.21
4							bare
7	.26	.30	.25	.21	.23	.21	
8						bare	
10	.27	.32	.27	.23	.25		
11					bare		
12	.30	.34	.30	.25			
13	.31	bare	.30	.25			
14	bare		bare	bare			
<u>1973</u>							
Nov. 1-Feb. 28	0.05	0.07	0.05	0.06	0.05	0.06	0.06
Mar. 1-31	.14	.07	.07	.09	.03	.05	.06
April 21	.17	.12	.12	.13	.11	.10	.06
22							bare
23	.18	.13	.13	.14	.13	.11	
24						bare	
26	.19	.15	.15	.16	.14		
27					bare		
May 1	.21	.18	.18	.18			
2				bare			
5	.25	.23	.21				
6		bare	bare				
11	.25						
12	bare						

¹Station 42

²Station 40

Table E2.--Mean daily percolation during winter and spring periods on south slope,
in inches

Date	Distance from west edge of forest, in feet					
	1,000	400	100	25	0 ¹	0 ²
<u>1970</u>						
Nov. 1-Feb. 28		0.08	0.06	0.04	0.07	
Mar. 1-31		.25	.22	.10	.07	
April 10		.36	.28	.16	.12	
13		.36	.28	.17	.12	
14		bare				
29			.31	.18	.13	
30			bare			
May 4				.27	.24	
5				bare	.24	
6					bare	
<u>1971</u>						
Nov. 1-Feb. 28	0.11	0.10	0.11	0.09	0.13	0.12
Mar. 1-31	.10	.05	.07	.07	.05	.03
April 10	.31	.26	.25	.20	.19	.13
13	.30	.29	.25	.21	.20	.20
14	bare		bare			
20		.37		.25	.25	.14
21		bare				
24				.30	.26	.16
25					bare	
26				.30		.17
27				bare		
May 4						.24
5						bare
<u>1972³</u>						
Nov. 1-Feb. 29	.09	.09	.08	.08	.10	.09
Mar. 1-31	.37	.41	.37	.30	.38	.33
April 1	.37	.42	.36	.31	.39	.33
2	bare	.41	bare	.31	.39	.33
3		bare				
25				.30	.31	.25
26				.29	bare	.25
27				bare		
May 4						.27
5						bare
<u>1973</u>						
Nov. 1-Feb. 29	.08	.05	.07	.05	.09	.10
Mar. 1-31	.20	.19	.19	.11	.13	.09
April 3	.23	.23	.23	.13	.16	.09
4	bare		.24	.15	.18	.11
5			bare			
6		.27		.16	.17	.11
7		.27		.17	bare	.11
8		bare				
9				.19		.12
10				bare		
11						.14
12						bare

¹Station 47

²Station 47.7

³Early rainfall and melt of seasonal snowpack, followed by intermittent snow-rainfall and subsequent melt, particularly in clearings.

Haupt, Harold F.

1979. Local climatic and hydrologic consequences of creating openings in climax timber of north Idaho. USDA For. Serv. Res. Pap. INT-223, 43 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Climatic and hydrologic responses of small and large clearcuts on north and south aspects in northern Idaho were studied. Other attributes such as drip, snow interception, snowmelt, and rates of disappearance were evaluated with supportive data.

KEYWORDS: snowpack, snow accumulation, snowmelt, coniferous forests, forest hydrology, forest meteorology.

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Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

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